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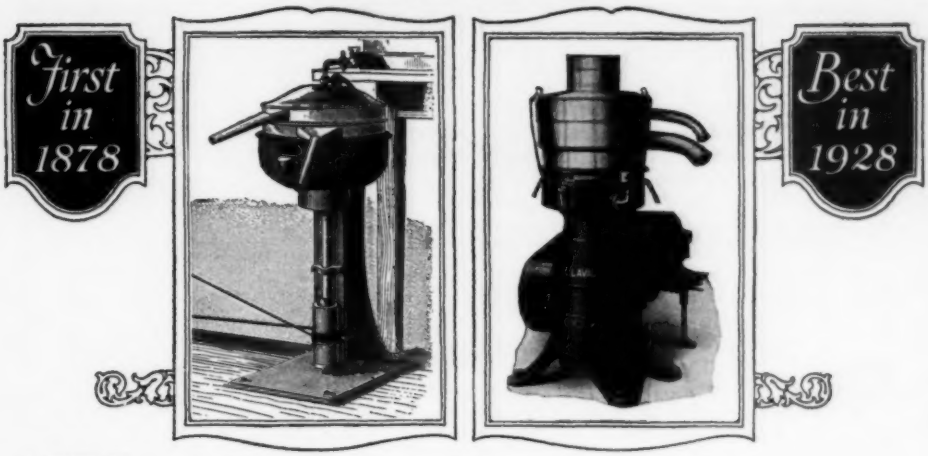

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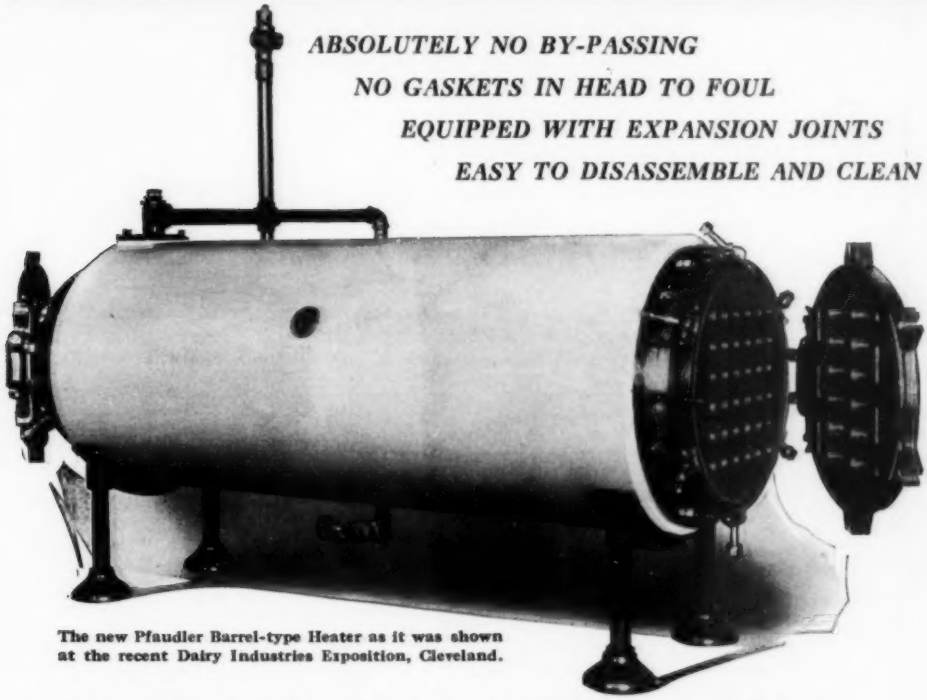

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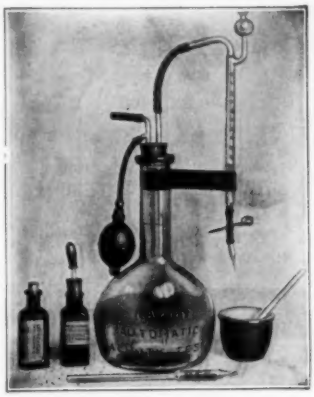

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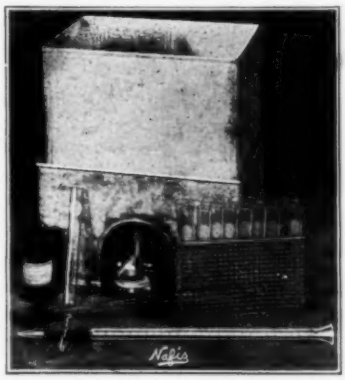

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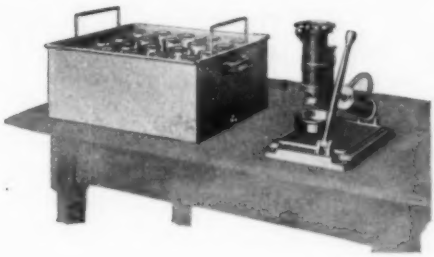

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CALF MEAL STUDIES

I. LABORATORY EXPERIMENTS IN THE IMPROVEMENT OF PHYSICAL CONDITION

II. FEEDING EXPERIMENTS WITH COOKED AND UNCOOKED MEAL*

J. G. ARCHIBALD

Massachusetts Agricultural Experiment Station, Amherst, Massachusetts

INTRODUCTION

For several years the Massachusetts Agricultural Experiment Station has been studying the problem of rearing calves with a minimum of milk. Several experimental calf meals have been worked with, some of which have been fairly satisfactory. In the earlier stages of the investigation, the empirical feeding trial was the sole method of attack, but more recently an attempt has been made to improve the meal which produced the most satisfactory growth, keeping in mind the underlying reasons for the excellence of milk as a food. One of these reasons is its physical condition. Milk is one of the best natural examples of an almost perfect emulsion, its solids (fat excepted) being in either colloidal or molecular dispersion, and remaining so indefinitely if bacterial action and other external influences are inhibited. The idea occurred that it might be possible to improve our best calf meal in this respect and, as a search of the literature revealed that very little had ever been done on the problem, it was considered worthy of investigation.

METHOD OF PROCEDURE

It was considered that possible improvement in the physical condition of a calf meal, and hence of the gruel made from it, might be effected in three ways: (1) by increase in fineness of division of the solids, (2) by addition of a protective colloid to aid in maintaining the dispersion of the solids, and (3) by partial cooking of the mixture.

* Published with the approval of the Director of the Massachusetts Agricultural Experiment Station. Received for publication November 10, 1927.

The laboratory method used to judge the efficacy of these several measures was the suspension test, i.e., the ability of the solids of a suspension made from the meal to remain dispersed in the liquid. The suspensions were made by mixing the meal with cold water in the same proportions as have been used in making up the gruels for feeding purposes, which has been 3½ ounces of meal to one quart of water, about 1 to 10.

The majority of the tests were made in 250 cc. beakers, using 200 cc. of water and 20.97 grams of meal. A few of the tests where the application of heat was not involved were made in tall glass cylinders, using a column of liquid 11 inches in height.

Combinations of all three measures were worked with in the laboratory and where a considerable improvement that could be effected in practice was noted, it was subjected to the following tests: (1) Feeding trials with calves, growth being noted by the increase in live weight, height at withers, and heart girth, during each week, and (2) digestion experiments of a week's duration with some of the calves.

I. LABORATORY EXPERIMENTS

The calf meal used for the work was designated as meal number 7. In earlier feeding trials it had produced growth in calves during the period from three weeks to four months of age, at the average rate of 1.2 pounds daily, 360 pounds of dry matter being required for 100 pounds of gain, 250 pounds of the dry matter coming from the calf meal, the balance from small amounts of whole and skim milk and what rowen the calves would eat. The meal was formulated from the following ingredients:

	pounds
Soluble blood flour	5
Skim milk powder	15
Linseed meal	15
Red dog flour	15
Low-grade oat meal	30
Corn starch	19
Calcium chloride	½
Sodium chloride	½
Total	100

The meal used for laboratory tests was prepared in the same manner as that used in the actual feeding experiments, the ingredients being thoroughly mixed and the mixture sifted through a 2 mm. sieve. The siftings were ground in a laboratory mill until they would pass the 2 mm. sieve, and were then mixed with the rest of the meal.

In some of the laboratory tests a good grade commercial calf meal was used in comparison with the number 7 meal. Judging by the manufacturer's statement it was similar in make-up to

TABLE 1

	NUMBER 7 MEAL (AVERAGE OF FOUR ANALYSES)	COMMERCIAL MEAL (ONE ANALYSIS)
	per cent	*per cent*
Moisture as fed	8.5	8.7
Dry matter:		
Crude protein	24.6	17.7
Ether extract	4.0	4.0
N-free extract	64.4	69.2
Crude fiber	2.7	4.6
Ash	4.3	4.5
	NUMBER 7 MEAL	COMMERCIAL MEAL
	per cent	*per cent*
Larger than 2 mm	0.23	1.38
Larger than 1 mm	13.12	14.51
Larger than ½ mm	22.46	33.93
Larger than 100 mesh	41.95	55.61
Smaller than 100 mesh	58.05	44.39

the experimental meal. The proximate chemical analyses and the mechanical analyses of the two meals are given in table 1.

The experimental meal was somewhat superior theoretically to the commercial article. It was in somewhat finer mechanical condition and contained considerably more protein and less fiber. Microscopic examination of its finer material revealed a maximum particle size of about 50 μ, with most of the particles ranging from 2 to 3 μ, as compared with a maximum size of 100μ or more, in the finer material from the commercial meal, and much greater variation in size of particles.

The results of a suspension test with the two meals are given in table 2. The tests were made in 250 cc. beakers.

This adds further evidence in favor of the superior physical condition of the experimental calf meal. Similar tests were made

TABLE 2

Suspension test of calf meals

ELAPSED TIME AFTER MIXING	AMOUNT OF SEDIMENT		CHARACTER OF THE SUPERNATANT LIQUID	
	No. 7 meal	Commercial meal	No. 7 meal	Commercial meal
	inches	*inches*		
5 minutes	$\frac{7}{8}$	$1\frac{1}{4}$	Turbid	Clearing at the top
15 minutes	$\frac{7}{8}$	$1\frac{1}{8}$	Still turbid	Continues to clear
1 hour	$\frac{13}{16}$	$1\frac{1}{4}$	Still turbid	Gradually clearing
18 hours	$\frac{7}{8}$	$1\frac{1}{8}$	Still turbid	Upper portion fairly clear

Note. The decreasing values for amount of sediment in the later readings are due to more complete settling of the sediment.

TABLE 3

Suspension test of calf meal No. 7 in comparison with skim milk powder

ELAPSED TIME AFTER MIXING	AMOUNT OF SEDIMENT			CHARACTER OF SUPERNATANT LIQUID		
	Skim milk powder (spray dried)	Skim milk powder (drum dried)	No. 7 calf meal	Skim milk powder (spray dried)	Skim milk powder (drum dried)	No. 7 calf meal
		inches	*inches*			
15 minutes	None	$1\frac{1}{8}$	$\frac{15}{32}$	Does not clear at all, solids remain in perfect suspension	Clearing	Quite turbid
30 minutes	None	$1\frac{1}{8}$	$\frac{3}{4}$		Clearing	Clearing slightly
1 hour	None	$1\frac{1}{32}$	$\frac{3}{4}$		Clearing	Not much change
24 hours	None	$1\frac{1}{4}$	$\frac{3}{4}$		Quite clear	Translucent but not clear

on it in comparison with skim milk powder. These were made in tall glass cylinders. The results are reported in table 3.

The number 7 meal occupied a position about midway between the two types of skim milk powder insofar as the suspension test is concerned. The ideal meal in this respect would be one that would remain in as perfect dispersion as did the "spray dried"

skim milk powder. In the nature of things this is a practical impossibility but what improvement could be made was attempted by the methods outlined on p. 119.

1. Increase in fineness of division of the solids

This was effected by grinding the meal in a ball mill until it would all pass through a sieve having 100 meshes to the linear inch. The effect of this treatment on degree of dispersion is shown by the suspension test reported in table 4. The data on the original meal are a repetition, for comparison, of those in table 2.

TABLE 4

Effect of fine grinding on degree of dispersion of the No. 7 meal

ELAPSED TIME AFTER MIXING	AMOUNT OF SEDIMENT		CHARACTER OF THE SUPERNATANT LIQUID	
	No. 7 meal (original)	No. 7 meal (100 mesh)	No. 7 meal (original)	No. 7 meal (100 mesh)
	inches	inches		
5 minutes	$\frac{1}{8}$	Boundary between liquid and sediment not distinct	Turbid	Very turbid
15 minutes	$\frac{1}{8}$	$1\frac{1}{2}$	Still turbid	Very turbid
1 hour	$\frac{1}{8}$	$1\frac{3}{16}$	Still turbid	Very turbid
18 hours	$\frac{1}{8}$	$1\frac{3}{16}$	Still turbid	Quite turbid, muddy brown color

The grinding increased somewhat the ability of the meal to remain in supension, but reducing the meal to such a degree of fineness was so time-consuming as to be impracticable; also, this fine meal had a decided tendency to "ball" or "lump" when wetted, and was much harder to mix with water than was the original meal. The apparent larger amount of sediment in the 100 mesh product is due to the much bulkier nature of the suspended solids, the particles being so fine that they did not settle out into a compact layer of sediment, such as was noted with the original meal.

2. Addition of a protective colloid

Gelatin was used in this phase of the work, the percentage strengths employed being $\frac{1}{10}$, $\frac{1}{2}$, 1, 2 and 5 per cent of the weight of the dry meal. The gelatin was dissolved in the water used for making the gruel before adding the meal. Table 5 shows the effect of gelatin when added to a suspension of the original meal made with water at room temperature.

TABLE 5

Effect of gelatin on degree of dispersion (cold water suspension)

ELAPSED TIME AFTER MIXING	Percentage strength of gelatin: NONE	0.1 PER CENT	0.5 PER CENT	1 PER CENT	2 PER CENT	5 PER CENT
Sediment						
	inches	*inches*	*inches*	*inches*	*inches*	*inches*
5 minutes	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$
15 minutes	$\frac{1}{8}$	1	$\frac{15}{16}$	$\frac{31}{32}$	$\frac{31}{32}$	$\frac{1}{8}$
1 hour	$\frac{1}{16}$	$1\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$1\frac{1}{32}$	$\frac{1}{16}$
24 hours	$1\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{1}{16}$	1	$1\frac{1}{16}$	$\frac{1}{16}$
Supernatant liquid						
5 minutes	Very turbid	Very turbid	Very turbid	Very turbid	Very turbid	Very turbid
15 minutes	Very turbid	Very turbid	Very turbid	Very turbid	Very turbid	Very turbid
1 hour	Very turbid	Very turbid	Very turbid	Very turbid	Very turbid	Very turbid
24 hours	All tests disturbed by fermentation					

Apparently gelatin had little or no effect on the degree of dispersion of a cold water suspension of the original meal. Its effect when the suspension was heated, and on the 100 mesh meal is discussed on pp. 127, 128 and 129.

3. Partial cooking of the mixture

The suspensions were made up as before and gentle heat was applied with constant stirring until a definite temperature was reached. The temperatures chosen were 37°C. (blood heat) and 60°C. (the coagulation temperature of protein). With the 37°

tests the gruels were held at that temperature for several minutes but the 60° tests were brought to that temperature and removed from the source of heat at once. The temperature in every case was raised quite slowly in order that the full effect of the heat might be obtained. The Number 7 meal and the commercial

TABLE 6

Effect of heating on suspensions of calf meal

ELAPSED TIME AFTER MIXING	AMOUNT OF SEDIMENT		CHARACTER OF THE SUPERNATANT LIQUID	
	No. 7 meal	Commercial meal	No. 7 meal	Commercial meal
	Temperature—20°C. (room)			
	inches	*inches*		
5 minutes	3/4	1 1/2	Turbid	Clearing at top
15 minutes	3/4	1 5/16	Still turbid	Continues to clear
1 hour	11/16	1 1/4	Still turbid	Gradually clearing
18 hours	3/4	1 1/8	Still turbid	Upper portion fairly clear
	Temperature—37°C.			
5 minutes	1 7/16	2	Turbid	Clearing at top
15 minutes	1 1/8	1 1/8	Does not clear	Clearing slightly
1 hour	1 1/4	1 7/16	Does not clear	No change
18 hours	1 1/8	1 5/16	Does not clear; very turbid	No change
	Temperature—60°C.			
5 minutes	2 3/8*	1 5/16	No supernatant liquid	Quite turbid
15 minutes	2 5/16	1 1/8	Very slight layer of supernatant liquid	Still turbid
1 hour	2 7/16	1 7/16	Layer slightly deeper	Still turbid
18 hours	1 3/4	1 1/8	Layer 1/4 inch in depth	No change

* Entire column—not settled out any.

meal were both used in this series of tests. The results are tabulated in table 6, the data in table 2 being repeated for ready comparison.

Heating the mixtures increased the ability of the meals to remain in suspension, noticeably at 37°, markedly at 60°. When subjected to the latter temperature the solids of the gruel re-

mained in practically complete suspension for an hour and had not settled out to any great degree at the end of eighteen hours. The effect was somewhat more marked with the Number 7 meal than with the commercial meal.

TABLE 7

Effect of a combination of fine grinding and heating

ELAPSED TIME AFTER MIXING	AMOUNT OF SEDIMENT	CHARACTER OF SUPERNATANT LIQUID
	No. 7 meal (100 mesh)	No. 7 meal (100 mesh)
	Temperature—20°C. (room)	
	inches	
5 minutes	Boundary between liquid and sediment not distinct	Very turbid
15 minutes	1½	Very turbid
1 hour	1 5/16	Very turbid
18 hours	1 5/16	Quite turbid, muddy brown color
	Temperature—37°C.	
5 minutes	Not definite, about 2 inches	Very turbid, slightly darker than the unheated
15 minutes	Not definite, about 2 inches	Very turbid, slightly darker than the unheated
1 hour	1 11/16	Quite turbid
18 hours	1 5/16	Quite turbid
	Temperature—60°C.	
5 minutes	None—uniform throughout	None—uniform throughout
15 minutes	2½	Slight layer at top
1 hour	2 1/16	One-quarter inch layer at top, fairly turbid
18 hours	1 11/16	Quite turbid

4. Partial cooking and fine grinding

Portions of the 100 mesh meal were mixed with water and heated as described in the previous section. The data on the suspension tests appear in table 7, a portion of the data in table 4 being repeated for comparison. The Number 7 meal only was used in these tests.

The effect of heat on the finely ground meal was similar to that

on the meal as ordinarily fed. The efficacy of fine grinding, as set forth in table 4, for the unheated suspension, was not so noticeable when 37° heat was applied and was completely offset by heating

TABLE 8

Effect of adding gelatin and heating

ELAPSED TIME AFTER MIXING	Percentage strength of gelatin: NONE	⅛ PER CENT	¼ PER CENT	1 PER CENT	2 PER CENT	5 PER CENT
	Temperature—37°C.					
	inches	*inches*	*inches*	*inches*	*inches*	*inches*
Sediment						
5 minutes	1/8	1	1 1/8	1 1/8	1 1/8	1/8
15 minutes	1 1/8	1 1/16	1 1/16	1 1/16	1 1/8	1 1/16
1 hour	1 1/16	1 1/16	1 1/16	1 1/16	1 1/16	1
24 hours	All tests disturbed by fermentation					
Supernatant liquid						
5 minutes	Very turbid	Very turbid	Very turbid	Very turbid	Very turbid	Very turbid
15 minutes	Very turbid	Very turbid	Very turbid	Very turbid	Very turbid	Very turbid
1 hour	Clearing some	Still very turbid	Still very turbid	Still very turbid	Still very turbid	Still very turbid
24 hours	All tests disturbed by fermentation					
	Temperature—60°C.					
Sediment						
5 minutes	2 1/8	2 1/8	2 1/8	2 1/16	2 1/16	2 1/16
15 minutes	2 1/8	2 1/16	2 1/16	2 1/16	2 1/16	2 1/16
1 hour	1 1/16	1 1/8	1 1/16	1 1/8	1 1/16	1 1/8
24 hours	All tests disturbed by fermentation					
Supernatant liquid						
5 minutes, 15 minutes	Little or none—solids distributed throughout almost the entire column of liquid					
1 hour	Similar in all, the cooking produced a gel which slowly settled out, leaving the supernatant liquid quite clear					
24 hours	All tests disturbed by fermentation					

to 60°C., (see table 6). Presumably the cooking partially hydrolyzed the starches and gums in the meal so that a hydrogel was formed which was viscous enough to hold in suspension not only

the fine particles of the 100 mesh meal but also the coarser particles of the original meal.

5. Partial cooking and addition of gelatin

The strengths of gelatin used were those already noted in section 2, and the method of preparing and heating the suspensions was as previously described. The Number 7 meal was used for all the tests, results appearing in table 8 (compare with table 5).

TABLE 9

Effect of fine grinding and adding gelatin

ELAPSED TIME AFTER MIXING	AMOUNT OF SEDIMENT		CHARACTER OF SUPERNATANT LIQUID	
	Control	5 per cent gelatin	Control	5 per cent gelatin
	inches	inches		
5 minutes	Settling evident but no definite sediment	No definite sediment	Very slight layer at top, not clear	None
15 minutes	Settling slowly but no definite sediment	Settling some but not as much as the control	The slight layer is still very turbid	Very slight layer—very turbid
1 hour	1⅛	No definite sediment	Still quite turbid	Very turbid
2 hours	1¼	No apparent change from one hour	Translucent rather than turbid	Very turbid
18 hours	1	Very little change, holding up well	Fairly clear	Very turbid

With 37° heat the gelatin helped a little during the first hour or so. The 5 per cent test held the solids in suspension noticeably better than did any of the others, while the control test was somewhat inferior to any of the gelatin tests. With 60° heat none of the gelatin tests were in any way superior to the control. Presumably heating to this temperature hydrolyzed the starch so that it had a protective action equal to, if not greater than, the added gelatin.

6. Fine grinding and addition of gelatin

For this test the 5 per cent strength of gelatin only, was used, in a suspension of the 100 mesh meal. Results are given in table 9.

The addition of the gelatin increased considerably the ability of the 100 mesh meal to remain in suspension. The result here is somewhat different from that obtained when gelatin was added to a suspension of the original meal (see table 5). The assumption is that in the latter case the particles were not fine enough for the protective action of the colloid to have any appreciable effect.

TABLE 10

Effect of a combination of all three agencies

ELAPSED TIME AFTER MIXING	AMOUNT OF SEDIMENT (INCHES)		CHARACTER OF SUPERNATANT LIQUID	
	Control	5 per cent gelatin	Control	5 per cent gelatin
5 minutes	Uniform dispersion throughout in both			
15 minutes	Slight layer of clear supernatant liquid at top of each column, otherwise uniformly dispersed			
1 hour, 2 hours, 18 hours	The slight layer of clear supernatant liquid in both tests increased slightly during each time interval, but the solids remained uniformly dispersed, with no separation into layers of coarser and finer particles			

7. Fine grinding plus gelatin plus partial cooking

The tests were identical with those in the last section, except that they were heated to 60°C. The results appear in table 10.

The good effect of the added gelatin noted in the last section was completely offset by heating to 60°C., the gelatin test being no better than the control. The explanation offered is the same as given in section 5 on p. 128.

CONCLUSION FROM LABORATORY WORK

1. A reasonable degree of fineness is requisite in a calf meal, but very fine grinding is impracticable, and may be unnecessary.

2. Gelatin, taken as a type of protective colloids, is without effect on calf meal gruels as ordinarily prepared. This is con-

sidered to be due to the fact that the particles are too large for the protective action to take place.

3. Moderate heating (not above 60°C., because of protein coagulation above that temperature) seems to be the most efficacious manner of improving the physical condition of calf meal gruels as manifested by increasing the dispersion of the solids. It accomplishes the same end as does fine grinding, or addition of gelatin, or both, and is much more nearly practicable than the first mentioned.

II. FEEDING EXPERIMENTS

Having reached the conclusion just stated, the next step was to carry on some feeding experiments to ascertain whether the partially cooked meal was an improvement in practice over the raw meal.

Ten grade Holstein bull calves ranging in age from one to four days were obtained and reared on whole milk, skim milk and calf meal Number 7 in the usual manner.[1] They were divided into two groups of five each, one group receiving the raw meal, the other the meal heated to 60°C. as described on p. 124. Division into groups was made largely on the basis of live weight at the commencement of the experiment, although apparent vigor was

[1] The following excerpt from Massachusetts Agricultural Experiment Station Bulletin No. 223 describes the method of feeding:

"Our method of feeding has been planned so as to have the calves weaned from whole and skim milk as early as possible. The calves are left with their dams only twenty-four hours, at the end of which time they are taught to drink whole milk from a pail. The milk fed to them is always from one of the lowest testing Holstein cows in the herd, and the maximum fed is six quarts daily. When the calf is a week to ten days old the whole milk is gradually replaced by skim milk. If it is a vigorous animal it will be receiving skim milk entirely by the end of the second week. When the calf is from two to three weeks old the skim milk is gradually replaced, a quart at a time, by a gruel made from the meal which it is desired to give a trial. The gruel is made by mixing the meal with water in the proportion of 3½ ounces of meal to each quart of water. It is stirred up with a little cold water first so lumps will not form, and then the correct amount of warm water is added, and the gruel fed at blood heat, never cold or very hot. Skim milk, while it continues to be fed, is mixed with the gruel at feeding time."

also considered. Average figures for weight, height at withers, and heart girth, at one week of age, appear below.

	WEIGHT	HEIGHT	GIRTH
	pounds	*inches*	*inches*
Group 1 (raw meal)	90.6	29.5	31.7
Group 2 (cooked meal)	92.0	29.3	30.9

The average age at which the calves first received the calf meal gruel was 19.4 days, Group 1 commencing at 19 days and Group 2 at 19.8 days. All calves continued to receive the gruel until they were four months of age at which time the experiment was

TABLE 11

Feed consumption and gains

GROUP	WHOLE MILK	SKIM MILK	CALF MEAL NO. 7		HOWES	TOTAL DRY MATTER CONSUMED	TOTAL GAIN	AVERAGE DAILY GAIN	DRY MATTER REQUIRED FOR 100 POUNDS OF GAIN
			As gruel	As dry meal					
	quarts	*quarts*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
1 (raw meal)	188	76	171	61	116	378	126	1.05	298
2 (cooked meal)	185	94	157	65	116	373	115	0.95	334

discontinued. Table 11 contains the records of average feed consumption and gains.

In addition the accompanying figures showing the average growth curves give the results at a glance, (see figs. 1 and 2).

All the records of the feeding trials are consistently in favor of the raw meal, although at the start the two groups were about as identical as it is possible to have groups which are composed of living individuals. The partially cooked meal apparently was less palatable than the raw meal as the amount of liquid feed refused was considerably higher where it was fed. This lower feed consumption explains in part the less favorable growth records, but it was evident all through the experiment that this group of calves were not making as good use of what they actually

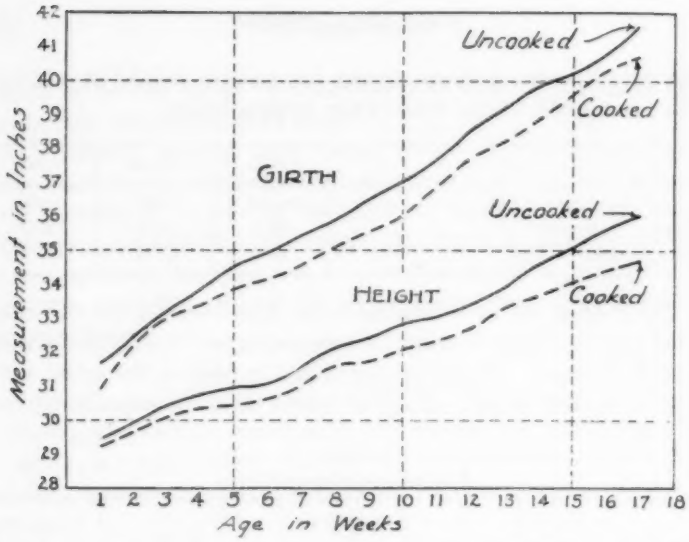

FIG. 1. AVERAGE WEIGHTS IN CALF MEAL EXPERIMENT—5 CALVES IN EACH GROUP

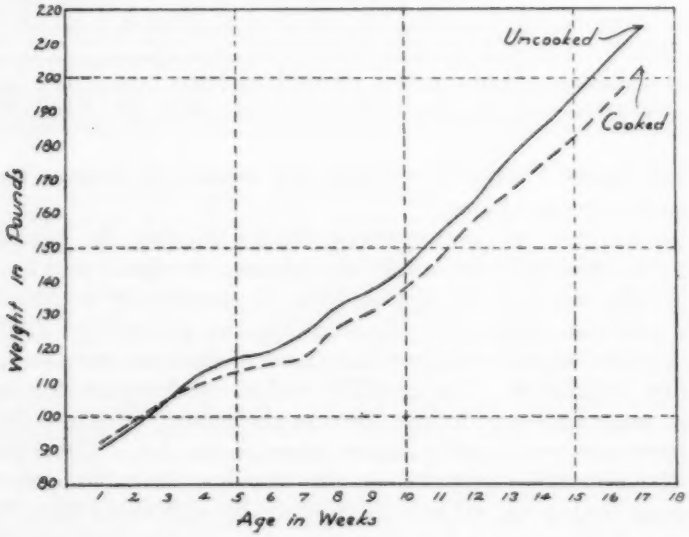

FIG. 2. AVERAGE GROWTH CURVES IN CALF MEAL EXPERIMENT—5 CALVES IN EACH GROUP

consumed as were those receiving raw meal gruel. They showed a greater tendency to scour and to develop the "pot belly" so characteristic of an unthrifty calf. Observation of their behavior leads to the belief that the unsatisfactory results with the cooked meal were largely due to excessive fermentation in the intestinal tract, evidently favored by the partial cooking. If there was any favorable influence due to the improved physical condition of the cooked gruel, it was not in evidence.

Digestion experiments were also carried on with six of the calves. These were conducted in pairs, on calves of the same

TABLE 12

Digestibility of calf meal No. 7 (raw and cooked)

	DRY MATTER	CRUDE PROTEIN	CRUDE FIBER	N-FREE EXTRACT	ETHER EXTRACT
Uncooked meal					
Calf 108	72.14	78.81	None	73.54	94.85
Calf 110	76.97	79.25	None	76.70	95.24
Calf 112	65.81	76.63	None	63.67	95.27
Average	71.64	78.23	None	71.30	95.12
	±1.25	±0.61	—	±2.65	±0.09
Cooked meal					
Calf 109	73.97	79.45	None	72.84	95.41
Calf 111	74.10	73.27	None	74.17	95.04
Calf 115	75.71	69.50	None	79.97	93.56
Average	74.59	74.07	None	75.66	94.67
	±0.22	±1.94	—	±1.48	±0.38

age, one calf being fed the raw meal gruel and the other the partially cooked gruel. The average age of the calves when the digestion trials were started was nine weeks. Each trial lasted ten days, collection of urine and feces being made on each of the last seven days. The ration fed during the trials was identical in all cases, viz., seven quarts of calf meal gruel containing 24½ ounces of meal, and two quarts of whole milk, per calf daily. In only one instance was any food wasted, the amount of waste being equivalent to 5½ per cent of the total dry matter fed. The summarized data of the digestion experiments appear in table 12.

In total dry matter and nitrogen-free extract the cooked meal was slightly more digestible, while its protein was less digestible. The question may be raised as to why, if the cooked meal was more digestible, it did not induce greater growth than did the uncooked meal. The probability is that the difference was only apparent, being due to bacterial fermentation with the production of large amounts of gases, rather than to true enzymatic digestion. The point to be emphasized is the failure of the cooking to have any marked effect on digestibility, either favorable or otherwise.

TABLE 13

Feed consumption and gains on skim milk powder + red dog-hominy

GROUP	WHOLE MILK	SKIM MILK POWDER	RED DOG-HOMINY	DRY GRAIN* NO. 5	ROWEN	TOTAL DRY MATTER CONSUMED	TOTAL GAIN	AVERAGE DAILY GAIN	DRY MATTER REQUIRED FOR 100 POUNDS OF GAIN
	quarts	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
Raw red dog-hominy.....	167	164	114	93	170	541	198†	1.64	272
Cooked red dog-hominy.....	138	161	129	87	141	511	183	1.50	280

* This is not the red dog-hominy mixture but a grain mixture composed of corn meal, ground oats, linseed meal, red dog flour and salt.

† At end of four months.

In addition to the results of the feeding trials reported in the previous section, the data from eleven calves used in the study of the general problem of milk substitutes are of significance in this connection. These calves were reared on a gruel made from drum-dried skim milk powder and a grain mixture consisting of equal parts of yellow hominy meal and red dog flour, in the proportion of 3 ounces of skim milk powder and 1½ ounces of red dog-hominy mixture to one quart of water. When the calves became quite hearty (at an age varying from two to three months), the amount of red dog-hominy was gradually increased until they were receiving as much of it as of the skim milk powder, i.e., 3 ounces

per quart. For six of the group the red dog-hominy mixture was cooked to the consistency of a thin porridge with the necessary water and when cooled to about blood heat the skim milk was stirred in, and the gruel fed at once. For the other five, the skim milk powder and red dog-hominy were simply stirred up with lukewarm water at feeding time. Table 13 presents the records of average feed consumption and gains.

The calves fed the raw red dog-hominy were heartier, made somewhat higher gains and required slightly less feed for a given amount of gain than did those fed the cooked gruel.

CONCLUSIONS FROM THE FEEDING TRIALS

1. Cooking reasonably fine calf meals, although it changes their physical condition, by increasing the dispersion of the solids, does not appear to exert any favorable effect on growth. Very fine grinding of calf meals for feeding was not undertaken because of its impracticability, hence its effect as compared with cooking has not been measured.

2. Digestibility of a calf meal is not significantly affected by cooking.

THE ICE CREAM SCORING CONTEST AS A MEANS OF IMPROVING THE QUALITY OF ICE CREAM*

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INTRODUCTION

Since 1921 the Dairy Husbandry Department of the Kansas Experiment Station has held seven annual ice cream scoring contests. The quality of the ice cream submitted each year has shown noticeable improvement over the preceding year. The improvement has been especially marked in the sanitary quality as revealed by the bacteriological analyses on the samples submitted. It is not contended that these scoring contests have been solely or even largely responsible for the improved quality of the ice cream in this section of the country, but they certainly have been of educational value to the ice cream makers participating in the contests.

RULES OF THE CONTEST

The contest is open to any ice cream plant selling any part of its product in the state of Kansas, and several samples from plants in adjoining states have been entered. One or more two-gallon samples may be submitted, but it is expressly stated that they must be from the regular run of the plant and not specially prepared samples. Many plants send in more than one sample, using the contest as a means of securing information on the com-

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parative value of certain processes or ingredients. All samples are shipped so as to arrive in Manhattan four days before the contest. This allows time for the scoring of the samples by the official judge, and for making a chemical and bacteriological analysis of each sample.

On the specified date, representatives from the various plants, among whom are ice cream makers, managers, and superintendents, meet in Manhattan for a two day conference. Excellent programs have been given each year by specialists in the theoretical and practical phases of the ice cream industry. A great deal of interest is manifested in these meetings, the educational value of which would be difficult to estimate.

On the second day of the meetings, the samples of ice cream are opened for the inspection of everyone present. The samples are designated by number, and the identity is known only to the owner of the ice cream and the officials of the contest. At this time the official scores are announced, together with the results of the chemical and bacteriological analyses.

No prizes are offered for the high scoring sample, and, in fact, the name of the owner is not even announced. Great care is taken to preserve the educational features of the contest and to eliminate the competitive element. The objective of such a plan is to enable the ice cream makers to profit through the educational aspects of the program and through contacts which the meeting affords, but more especially to see how their product compares with that of others. Many ice cream makers learn through these meetings that a product, which they previously thought to be excellent, is, after all, of medicore or poor quality. By comparing their own product with others they can see the strong and weak points of each. Improvement, which is the aim of the contest, usually results. That the objective of the contest has been realized is clearly evident when the scores of the ice cream for each successive year are compared.

BACTERIOLOGICAL RESULTS

In table 1 are given the lowest, the highest, and the median count of the samples for each separate year, and of the entire

group for the seven years. The median count is obtained by alternately striking out the highest and lowest count until the middle value is reached. This value is believed to be more representative of a group of bacteriological analyses than the arithmetical average, due to the distorting effect of a single high count on the result obtained by averaging.

It will be noted that the median count for the first year of the contest (1921) was 200,000 per gram and that each successive year it was lower then the preceding year. A detailed examination of the individual analyses for each successive year shows very convincingly the improvement in the sanitary quality of the ice cream submitted. In lieu of the mass of detailed figures,

TABLE 1

The extremes and median counts on ice cream submitted to each of the seven annual scoring contests

	YEAR							VALUES FOR ALL SAMPLES
	1921	1922	1923	1924	1925	1926	1927	
	28 samples	39 samples	48 samples	53 samples	42 samples	35 samples	46 samples	291 samples
Low count	5,000	4,000	2,000	3,000	2,000	2,000	3,000	2,000
High count	20,000,000	27,000,000	45,000,000	1,000,000	2,400,000	2,500,000	14,300,000	47,000,000
Median count	200,000	87,000	80,000	70,000	53,000	46,000	32,000	66,000

table 2 is submitted and presents a fairly clear picture of the improvement in the sanitary quality of the ice cream as evidenced by lower bacterial counts.

Table 2 shows the per cent of the samples containing less than a specified number of bacteria per gram, for each year and for the entire seven years. For illustration, note that in 1921 only 17.9 per cent of the samples contained less than 20,000 bacteria per gram; in 1922 the same percentage obtained, but from 1923 to 1927 there was a consistent increase in the per cent of samples below this value. Again, note that in the first contest only 32.1 per cent of the samples contained less than 50,000 bacteria per gram, whereas in the last contest more than 60 per cent were in this group. A study of this table shows a tendency in each succeed-

ing contest for more samples to be classed in the low count groups, and fewer in the high count groups.

FLAVOR, BODY AND TEXTURE SCORES

In view of the fact that each year a different judge scored the various samples, it has been difficult to correlate the scores. Some judges regarded an excellent body and texture worth a perfect score, whereas others gave no perfect scores to any of the samples. Another factor that accentuated the difficulty of correlating the

TABLE 2

The per cent of samples of ice cream in the scoring contests (1921–1927) containing less than specified numbers of bacteria

	YEAR							VALUE FOR 7 YEARS
	1921	1922	1923	1924	1925	1926	1927	
	28 samples	39 samples	48 samples	53 samples	42 samples	35 samples	46 samples	291 samples
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
10,000 or less.....	14.3	5.1	18.7	15.1	14.3	22.8	17.4	15.5
20,000 or less.....	17.9	17.9	22.9	22.6	35.7	40.0	41.3	28.5
50,000 or less.....	32.1	38.5	37.5	37.7	47.6	51.4	60.9	44.0
100,000 or less.....	35.7	51.3	54.2	58.5	71.4	65.7	67.4	58.8
200,000 or less.....	57.1	59.0	70.8	73.6	78.6	77.1	73.9	70.8
300,000 or less.....	67.9	71.8	75.0	86.7	80.9	80.0	76.1	77.7
500,000 or less.....	78.6	74.3	75.0	90.6	85.7	80.0	80.4	81.1
1,000,000 or less.....	89.3	82.0	81.2	100.0	97.6	85.7	91.3	90.0
Over 1,000,000.....	10.7	18.0	18.8	0	2.4	14.3	8.7	10.0

scores for various years, was the fact that a different score card was used for the last two years. However, the scores each year for the various factors can be grouped into four groups; excellent, good, medium and poor. For example, each judge apparently regarded a certain number of samples as excellent in body and texture, and to these gave a score, which, in his estimation represented the relative value of an excellent sample. With some judges the score allotted to this group of samples was one or two points below perfect, whereas other judges gave perfect scores to all the samples in this group. Similarly, another group of

samples, not good enough to be excellent but better than the average, could be observed in the ratings given by each judge. In this way it has been relatively easy to select from the scores for each year, the number of samples in each of the four groups. This method of grouping the scores has been followed for flavor,

TABLE 3

Per cent of samples of ice cream which were classed as excellent, good, medium and poor

	1921	1922	1923	1924	1925	1926	1927
Flavor score							
Excellent	25.0	17.9	18.8	9.6	9.7	17.1	24.4
Good	21.5	15.5	27.1	26.9	48.8	51.4	48.9
Medium	28.5	43.6	43.8	44.2	29.3	25.7	15.5
Poor	25.0	23.0	10.3	19.3	12.2	5.8	11.2
Excellent and good	46.5	33.4	45.9	36.5	58.5	68.5	73.3
Medium and poor	53.5	66.6	54.1	63.5	41.5	31.5	26.7
Body and texture score							
Excellent	32.1	25.6	18.8	17.3	29.3	8.6	15.5
Good	28.6	28.2	43.7	51.9	26.8	51.4	48.9
Medium	28.6	30.8	31.3	26.9	21.9	28.6	31.2
Poor	10.7	15.4	6.2	3.9	22.0	11.4	4.4
Excellent and good	60.7	53.8	62.5	69.2	56.1	60.0	64.4
Medium and poor	39.3	46.2	37.5	30.8	43.9	40.0	35.6
Total score minus bacteria score							
Excellent	3.6	10.2	20.8	11.5	17.1	11.4	15.6
Good	21.4	46.2	33.3	32.5	46.3	45.7	73.2
Medium	60.7	33.3	37.5	42.3	26.8	34.3	8.9
Poor	14.3	10.3	8.4	13.7	9.8	8.6	2.3
Excellent and good	25.0	56.4	54.1	44.0	63.4	57.1	88.8
Medium and poor	75.0	43.6	45.9	56.0	36.6	42.9	11.2

body and texture, and total score minus the bacteria score. A further grouping of the scores has been made by combining the total number of excellent and good samples for one group, and the medium and poor samples for another group. This method of grouping has been followed for the purpose of determining if there has been any tendency toward an increase in the number of

samples in the better classes of ice cream. Table 3 shows the results of these groupings.

In the first section of table 3 the flavor scores are considered. A study of the figures for the individual groups does not indicate any uniform improvement in the flavor of the samples from year to year. There is, however, a noticeable tendency for fewer samples to fall into the medium and poor groups and a correspondingly greater number to be classed as good and excellent. From 1921 to 1927 there was an increase from 46.5 to 73.3 per cent in the number of excellent and good samples and a corresponding decrease from 53.5 to 26.7 per cent in the number of medium and poor samples.

Improvement in the body and texture of the ice cream, has been less noticeable than the improvement in the flavor. The figures in the second section of table 3 show that the number of samples scoring excellent and good in body and texture increased from 60.7 per cent in 1921 to 64.4 per cent in 1927. Figures for the intervening years show considerable variability in the per cent of high scoring samples, but viewing them as a whole there is some evidence that the body and texture of the ice cream submitted has improved.

Finally, in the last section of table 3 the total scores for all points except bacteria are considered. Here again the improvement over the seven year period is noticeable. The per cent of excellent samples increased from 3.6 to 15.6 per cent, and the per cent of good samples from 21.4 to 73.2 per cent. In 1927 only 2.3 per cent of the samples were classed as poor, as compared with 14.3 per cent in 1921. During the same period the number of samples classed as medium decreased from 60.7 to 8.9 per cent.

SUMMARY

1. The sanitary quality of the 291 samples of ice cream entered in seven annual scoring contests held at the Kansas State Agricultural College, has shown a marked improvement from year to year. With a median count of 200,000 bacteria per gram in 1921 there has been, without exception, a consistent reduction each year to 32,000 in 1927.

2. The samples for each year have been grouped into four classes, excellent, good, medium and poor. A study of these groups reveals a definite improvement in the quality of the ice cream from year to year as evidenced by the increase in the per cent of samples in the better (excellent and good) classes.

The per cent of samples classed as having excellent and good body and texture scores increased from 60.7 in 1921 to 64.4 in 1927.

By classifying the samples on a basis of the total score minus the score for bacteria count, the excellent and good samples increased from 25.0 per cent in 1921 to 88.8 per cent in 1927.

3. While it is not contended that these scoring contests have been solely responsible for the improvement in the quality of ice cream as evidenced by these data, they have been a contributing factor in the educational program for the ice cream manufacturers of this section of the country. These scoring contests have been of inestimable value to the ice cream manufacturers of this section. The success of the system in this state and the evident improvement in the quality of the ice cream, commends the adoption of a similar plan by other institutions as a part of their educational program.

THE KEEPING QUALITIES OF GHEE*

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INTRODUCTION

Milk fat is one of the very important human foods. In some parts of the world such as America, Europe and Australia it is used in the form of butter, while in India and certain other countries it is used principally as ghee.

Ghee is prepared by heating unsalted butter on a low fire for a considerable period and then straining; the heating evaporates considerable quantities of the water and the straining removes a part of the curd which the heating has tended to flocculate. The milk of various animals is used in making ghee, but in India the milk of the buffalo is the most widely employed.

The present paper reports certain observations made on the keeping qualities of ghee; these are believed to be of significance in their relationship to the general problem of the keeping qualities of butter.

USES AND PROPERTIES OF GHEE

Ghee is ordinarily employed on various types of bread and in the cooking of meat, fish, vegetables, rice, etc. Large quantities are used in the sweetmeat industry. It is utilized to a limited extent for medicinal purposes when it is prepared from cows' milk and especially when it is very old.

Because of the temperature used in the making, ghee has a pronounced heated flavor and odor. It never shows the waxy texture of butter and is commonly grainy and brittle. At rather high temperatures there may be considerable oiling off.

Ghee keeps well under temperature conditions that would be considered very unsatisfactory for butter. It seems probable that its manufacture developed because of the unfavorable

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conditions for the storage of butter prevailing in certain countries where the temperatures are often high and the facilities for cooling limited.

METHODS

Preparation of ghee. The ghee used was prepared by heating unsalted butter made from cows' milk in small quantities in an aluminum utensil over a gas burner. The temperature to which the butter was heated in making what was considered normal ghee varied from 122° to 130°C., depending somewhat on the season; in addition to the temperature, the sound and foaming of the heating material and the appearance of the curd were considered in deciding as to when the heating should be stopped.

Preparation of butter fat. The butter fat was prepared by melting the butter, without heating it hotter than 55°C., allowing the water and curd to settle and then decanting the fat and filtering it through filter paper.

Storage of ghee and other materials. The normal and abnormal ghee and the butter and butter fat used for comparison were all stored in glass containers of capacities of ½ or 1 pint. Except in the trials on the influence of light, the samples were stored in the dark; when held in the dark the containers were wrapped in paper as an additional protection.

Materials used for comparisons. The materials used for any comparison always came from the same lot of butter.

Judging the materials. The judging involved only the detection of defects; no attempt was made to set a definite score.

Chemical methods. In securing the samples of the various materials, cores were removed through the entire depths so as to compensate for any separation that may have occurred. Ghee and the purified butter fat were used directly for the fat constants, while the butter and the ghee to which water had been added were melted and the fat decanted and filtered. The samples taken for analysis were put in ½-pint milk bottles, warmed in a water bath and thoroughly stirred before weighing out.

Nitrogen determinations were made by the Kjeldahl method.

The moisture determinations were made with a Mojonnier tester following the procedure used with butter. For the acid values (milligrams of KOH required to saturate the free acids in 1 gram of fat) 20 grams (or occasionally only 10 grams) of fat were titrated with N/10 KOH after dissolving the fat in hot neutral alcohol. The iodine number was determined by the Hanus method, the Reichert-Meissl number by the Leffman and Beam method, the melting point by the Wiley method, while for the refractometer readings a Zeiss-Butyro-Refractometer was used.

EXPERIMENTAL

Keeping qualities of ghee

Keeping qualities of ghee and butter. A number of comparisons of the keeping qualities of ghee and butter were made at both room temperature and cooler temperature. In each trial the ghee kept very much better than the butter. At room temperature the butter was commonly off in flavor and odor in from one to two weeks while the ghee usually showed little if any deterioration throughout the entire holding periods, which varied from nineteen to twenty-three weeks. In the cooler the butter kept somewhat longer than at room temperature but its keeping qualities were still very limited as compared to those of ghee.

Keeping qualities of ghee and butter fat. The keeping qualities of ghee and butter fat were compared in two trials. Both the ghee and the butter fat kept very well at either room temperature or cooler temperature. In one comparison the ghee at both temperatures was off in flavor and odor after about nine weeks while the butter fat was still satisfactory after twenty weeks; the off condition in the ghee involved a cheesy odor which seemed to accompany the growth of mold.

One comparison included a second lot of butter fat which had been heated to 130°C. after its preparation in the usual way. This also kept very well at the two temperatures used during a holding period of twelve weeks.

Keeping qualities of normal ghee and abnormal ghee. Abnormal ghee was prepared by adding sterile water to approximate the water content of butter or by omitting the straining so that the

curd content was high. The keeping qualities of such ghee were compared with those of normal ghee.

Two comparisons of ghee and ghee with added water were made; in one only room temperature was employed, while in the other room temperature and cooler temperature were used. The ghee with the added water deteriorated rather quickly in both comparisons while the normal ghee was still satisfactory after the holding periods, which were twelve weeks in one instance and nineteen weeks in the other. The ghee with added water became cheesy and showed a growth of mold. In the comparison involving two holding temperatures there seemed to be little, if any, difference between them.

Normal ghee and unstrained ghee were compared in three trials, two including only room temperature, while the third included both room temperature and cooler temperature. In the trials made at room temperature only, both the normal and unstrained ghee remained satisfactory throughout the holding periods, one of which was seventeen weeks and the other nineteen weeks. In the third trial the unstrained ghee became cheesy after two weeks at room temperature and after three weeks at cooler temperature, while the normal ghee was satisfactory at both temperatures throughout the twenty-three-week holding period; the off condition again seemed related to the development of mold.

Keeping qualities of ghee in the dark and in the light. The keeping qualities of ghee in the dark and in diffuse light were compared at room temperature in seven trials. Two of the lots of ghee were made from good butter while five were made from poor butter.

In six of the seven trials the ghee held in the diffuse light developed a tallowy odor in from two to seven weeks, while in the remaining one, which involved ghee made from good butter, there was no tallowiness after the ten weeks holding. None of the samples of ghee held in the dark developed tallowiness. Two of the lots of ghee which showed the tallowy condition were also bleached; these had remained solidified throughout the holding period, while the others showed some liquid fat at the surface.

Keeping qualities of ghee made from poor butter. Six lots of ghee were prepared using poor butter and the keeping qualities of these studied. It was very evident that the quality of the butter influenced the quality of the ghee made from it and that the heated flavor and odor developed during the making of the ghee did not cover up serious flavor and odor defects in the original butter. This complicated the study of the influence of holding on the ghee.

In two of the lots of ghee from poor butter there seemed to be a deterioration on holding, while with the others there was no evident change after periods of from sixteen to twenty weeks. The deterioration did not involve a cheesy condition as was the case with the deterioration of normal and abnormal ghee already referred to.

TABLE 1

Nitrogen and moisture contents of lots of ghee prepared at different temperatures

GHEE HEATED UP TO	PER CENT TOTAL NITROGEN	PER CENT MOISTURE
°C.		
110	0.0035	0.336
120	0.0042	0.220
130	0.0056	0.183
140	0.0070	0.158

Effect of the temperature used in making on the keeping quality of ghee. A comparison was made of the keeping qualities of four lots of ghee prepared by heating to four different temperatures—110°, 120°, 130°, and 140°C. The ghee made with the two lower temperatures developed a slight off condition at both room temperature and cooler temperature, while that made with the two higher temperatures remained satisfactory during the holding period of twenty-three weeks. The off condition was not at all suggestive of the cheesy condition noted in a number of lots of deteriorated ghee.

The heated flavor and odor of the different lots of ghee seemed to vary somewhat and be proportional to the temperatures used in the preparation.

The four lots of ghee were examined for the total nitrogen and

TABLE 2

The constants of normal and abnormal ghee and butter fat before and after storage

SAMPLE	KEEPING CONDITION	QUALITY					CONSTANTS									
		When fresh	After 3 weeks	After 6 weeks	After 8 weeks	After 10 weeks	Acid value		Iodine number		Reichert-Meissl. number		Melting point		Refractometer reading at 40°	
							Fresh	2 months after	Fresh	2 months after	Fresh	2 months after	Fresh	2 months after	Fresh	2 months after
Normal ghee	Cooler temperature	Good ghee odor	O. K.	O. K.	O. K.	O. K.	0.41	0.53	34.5	34.6	28.0	27.9	30.8	30.9	41.0	41.4
	Room temperature in dark	Good ghee odor	O. K.	O. K.	O. K.	O. K.	0.41	0.53	34.5	35.1	28.0	27.7	30.6	30.8	41.0	41.5
	Room temperature in light	Good ghee odor	O. K.	O. K.	Very slightly tallowy	Slightly tallowy	0.41	0.67	34.5	35.3	28.0	27.9	30.8	31.0	41.0	41.4
Butter fat	Cooler temperature	Good butter odor	O. K.	O. K.	O. K.	O. K.	0.42	0.46	35.0	35.3	28.1	27.6	30.7	30.6	41.5	41.5
	Room temperature in dark	Good butter odor	O. K.	O. K.	O. K.	O. K.	0.42	0.48	35.0	35.3	28.1	27.6	30.7	30.6	41.5	41.4
	Room temperature in light	Good butter odor	O. K.	O. K.	Very slightly tallowy	Very slightly tallowy	0.42	0.46	35.0	35.9	28.1	28.1	30.7	30.9	41.5	41.6
Ghee not strained	Cooler temperature	Good ghee odor	O. K.	O. K.	O. K.	O. K.	0.41	0.47	34.5	35.6	28.0	27.5	30.8	31.0	41.0	41.7
	Room temperature in dark	Good ghee odor	O. K.	O. K.	O. K.	O. K.	0.41	0.50	34.5	35.8	28.0	27.6	30.8	31.2	41.0	41.0
	Room temperature in light	Good ghee odor	O. K.	O. K.	Very slightly tallowy	Very slightly tallowy	0.41	0.48	34.5	35.3	28.0	27.5	30.8	31.0	41.0	41.8

Ghee plus water	Cooler temperature	Good ghee odor	O. K.	O. K.	Off	Off and cheesy	0.41	0.45	34.5	35.5	28.0	27.1	30.8	30.9	41.0	41.5
	Room temperature in dark	Good ghee odor	O. K.	Off; mold growth	Very cheesy and off	Very cheesy and off	0.41	0.73	34.5	35.2	28.0	27.3	30.8	30.7	41.0	41.5
	Room temperature in light	Good ghee odor	Slightly off	Off; mold growth	Off; mold growth	Off; mold growth	0.41	1.03	34.5	34.7	28.0	27.2	30.8	30.6	41.0	41.5
Ghee from poor butter	Cooler temperature	Ghee odor, but slightly off	O. K.	O. K.	O. K.	O. K.	0.78	0.78	34.3	34.7	27.4	27.9	31.9	31.8	41.0	41.7
	Room temperature in dark	Ghee odor, but slightly off	O. K.	O. K.	O. K.	O. K.	0.78	0.81	34.3	35.0	27.4	28.0	31.9	31.9	41.0	41.7
	Room temperature in light	Ghee odor, but slightly off	O. K.	O. K.	Very slightly tallowy	Very slightly tallowy	0.78	0.82	34.3	35.0	27.4	28.2	31.9	31.6	41.0	41.8

the moisture contents because of the possible relationship of the temperature of heating to the composition. The results secured are given in table 1 and show that with an increase in the temperature of the heating there was an increase in the per cent of total nitrogen but a decrease in the per cent of moisture; the increased moisture content of the ghee made with the lower temperatures, although comparatively small, may have been a factor in causing a greater deterioration.

Composition and fat constants

Nitrogen and moisture. It would be expected that ghee would contain small amounts of protein and water because of their presence in butter. A number of lots of both ghee and butter fat were examined for these, but the amounts found were so small that considerable percentage error in the results is to be expected. With eight samples of normal ghee the per cent nitrogen varied from 0.000 to 0.019 and the per cent moisture from 0.039 to 0.166, while with three samples of butter fat the average values for nitrogen and for moisture were slightly lower.

Fat constants of ghee before and after storage. Certain fat constants were determined on (1) normal ghee, (2) butter fat, (3) unstrained ghee, (4) ghee with added water and (5) ghee made from poor butter, both before and after storage under different conditions. The results obtained are presented in table 2. From the data given it is evident that the constants on the fresh materials are in general agreement with the values usually found in the examination of butter. The principal change in the constants during holding was an increase in the acid value and in general this was most pronounced in the samples showing the greatest deterioration and small where the samples remained in a satisfactory condition. The iodine number, Reichert-Meissl number, melting point and refractometer reading showed no general change during the storage period.

Table 3 gives the fat constant on five samples of deteriorated ghee, two of which had been modified, together with the general defect noted. Here again the acid value shows the greatest change from what would undoubtedly be considered normal.

Relationship of mold to the deterioration of ghee

Molds of various types were generally present in ghee which was decidedly cheesy and accordingly it seemed desirable to study the relationship of molds to this condition.

TABLE 3

Constants on deteriorated ghee

SAMPLE	QUALITY WHEN ANALYSED	CONSTANTS		
		Acid value	Iodine number	Reichert-Meissl. number
Ghee plus curd	Very cheesy	1.16	31.8	28.3
Normal ghee	Cheesy	1.27	31.9	27.9
Ghee from poor butter in dark	Slightly off	1.01	31.5	28.0
Ghee from poor butter in light	Very tallowy	2.99	31.8	28.4
Ghee plus water	Very cheesy	1.23	31.7	28.3

TABLE 4

Observations and constants on normal and abnormal ghee, butter fat, and butter. All inoculated with mold

SAMPLE	QUALITY				CONSTANTS AFTER 6 weeks		
	When fresh	After 1 week	After 4 weeks	After 6 weeks	Acid value	Iodine number	Reichert-Meissl. number
Normal ghee	Good ghee odor	O. K.	O. K.	O. K.	0.81	36.5	27.35
Sterile butter fat	Slightly heated odor	O. K.	O. K.	Very slightly off	2.07	37.2	26.98
Ghee not strained	Good ghee odor	O. K.	O. K.	Very slightly off	1.57	36.8	27.50
Ghee plus water	Good ghee odor	Off; cheesy	Very cheesy	Very cheesy	9.18	36.4	27.00
Sterile butter	Slightly heated odor	Off; cheesy	Off; cheesy	Very cheesy	7.42	36.7	27.38

Various types of mold were isolated from cheesy ghee by pouring plates using whey agar. When these were inoculated into

butter which had been sterilized and cooled with agitation so as to reincorporate the water and curd, a cheesy condition commonly developed on standing in the dark at room temperature.

The influence of various factors on the growth of mold was then studied by preparing (1) normal ghee, (2) sterilized butter fat, (3) unstrained ghee, (4) ghee plus 16 per cent sterilized water and (5) sterilized butter, and cooling with agitation after which they were inoculated with mold. The samples were held in the dark at room temperature and examined at various intervals for quality; after six weeks some of the fat constants were determined and the results obtained are given in table 4. The data show that the butter and the ghee with the added water deteriorated rapidly and became cheesy; the normal ghee remained satisfactory, while the butter fat and unstrained ghee were very slightly off after six weeks. The principal change in the fat constants was an increase in the acid value and this increase was very pronounced in the case of the ghee with added water and the butter.

DISCUSSION OF RESULTS

From the results obtained it is evident that the ghee kept much better than the butter with which it was compared at both room temperature and cooler temperature. Butter fat, even when it had not been heated above 55°C., had keeping qualities much more nearly like ghee than like butter and this suggests that the elimination of water and curd were the factors giving ghee its keeping qualities, rather than the heat used in the manufacture. In accordance with this idea it was found that the addition of sterile water to ghee greatly decreased its keeping properties and that in one of three trials the failure to remove a part of the curd by straining resulted in a comparatively rapid deterioration. The general results obtained suggest that the presence of moisture is more important from the standpoint of deterioration than the presence of larger amounts of curd.

The exposure of ghee to diffuse light quite regularly resulted in the development of a tallowy condition and sometimes in

actual bleaching. This indicates the value of the practice of using earthenware or tin rather than glass for the storage of ghee.

The off flavor and odor in ghee made from poor butter show that the quality of the raw material, whether this be looked upon as milk, cream, or butter, is important with ghee just as it is with butter. The heat used in making ghee apparently does not remove or cover up off flavors and odors and it seems that considerable variation is to be expected in ghee made in small quantities because of variations in the quality of the raw material.

The higher the temperature used in making ghee, the more pronounced was the heated flavor and odor in the finished product. The higher temperatures also seemed to yield ghee with better keeping qualities; this may have been due to the less complete removal of the moisture with the lower temperatures.

The general results obtained on ghee suggest that its keeping properties are due to the composition. The elimination of water and curd makes conditions unfavorable for the growth of organisms and such hardy types as some of the molds have difficulty in developing.

The butter fat in a purified condition seemed to be quite resistant to the growth of microörganisms and other types of changes. Accordingly it would appear that in butter the constituents other than the fat are the important ones from the standpoint of deterioration. The conditions in butter are undoubtedly much more favorable for growth than in ghee and permit of the development of a greater variety of microörganisms than in the case of ghee where the growth seemed to be largely limited to molds.

The general findings suggest that the development of products made up almost entirely of butter fat may solve the problem of a food which can be used as butter and kept under severe temperature conditions. Such a product need not be prepared at high temperatures and thus the heated flavor and odor of ghee need not be present.

Analyses of ghee show that it contains only very small amounts of water or protein and its composition closely approaches that of butter fat.

During deterioration the principal change in the fat constants studied was an increase in the acid value. This suggests that the cheesy flavor and odor may be due to the liberation of certain fatty acids, such as caproic, caprylic and capric, which are believed to be important in accounting for the characteristic flavor and odor of Roquefort cheese. Definite changes did not occur in the iodine number, Reichert-Meissl number, melting point or refractometer reading, even when there were rather pronounced changes in flavor and odor. It seems probable that often the amount of any material required to give a definite off flavor and odor is so small it is difficult to detect the chemical change resulting in its formation.

SUMMARY

Studies on the keeping qualities of normal and abnormal ghee, butter and butter fat showed that ghee and butter fat kept much better than butter or ghee containing added moisture. This suggests that the composition is a big factor in the keeping qualities of these products. The addition of moisture seemed to favor the deterioration of ghee more than the addition of protein.

The flavor and odor of ghee which had developed a pronounced off condition were usually cheesy; in general the growth of mold accompanied the development of this condition.

The most definite change in the fat constants during the deterioration of ghee was an increase in the acid values.

A METHOD OF AWARDING MARKS FOR UNIFORMITY OF LOW BACTERIAL COUNT IN CLEAN MILK COMPETITIONS*

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In "Clean Milk Competitions" in England the cleanliness of a sample of milk is judged on three points, namely (1) the total number of organisms per cubic centimeter which grow on a standard nutrient agar, (2) the degree of infection by coliform organisms, as shown by the presumptive test and (3) the number of days which the milk remains sweet after milking when kept at a temperature of 60°F. Marks are awarded for the above points according to the scale suggested in the "Guide to the Conduct of Clean Milk Competitions (1926)" published by the Ministry of Agriculture. The competitions generally run for a period of six months, milk samples being taken at fortnightly intervals. The total number of marks awarded to a competitor under the three headings is in general taken to be an index of his ability to produce clean milk.

In this system of marking it will be noted that no account is taken of the consistency of cleanliness of successive examples of any one competitor. The graphs given in figures 1, 2, 3, and 4 show the percentage marks[1] awarded for each sample sent in by twelve competitors in a recent "Clean Milk Competition." From a study of these graphs it will be seen that there are cases in which the results of the samples sent in show extraordinary variations, due obviously to a disregard of the smaller, yet none the less important, details of clean milk production. Such a case is illustrated in the graph of competitor 2 (fig. 1). Here the competitor gained a 100 per cent of the marks for the fifth sample, yet on two occasions his samples were so poor that

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[1] These marks are also given in table 1.

no marks were awarded. On the other hand, there are cases in which, as the competition proceeds, the samples show consistently low bacterial counts, in some instances gradually decreasing, thus indicating a gradual improvement. The graphs of competitors

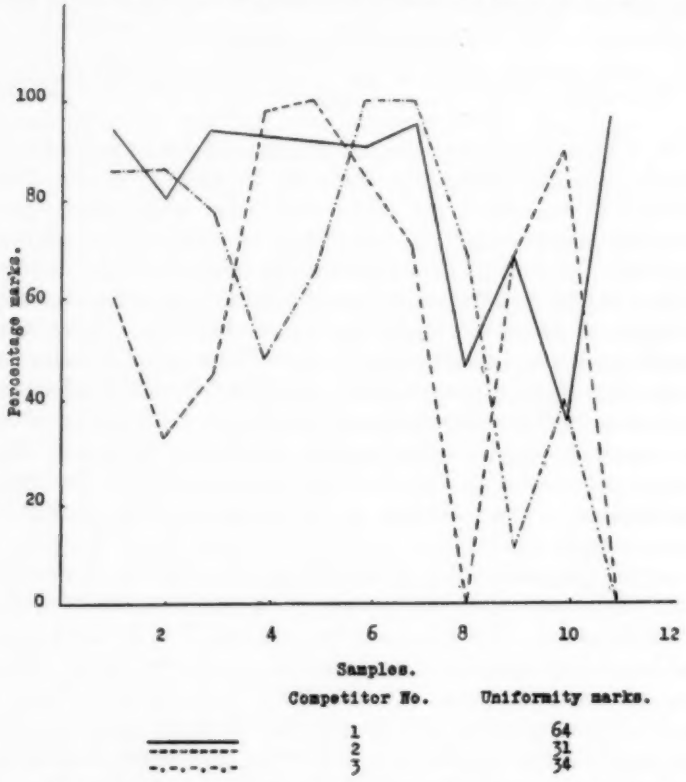

FIG. 1. GRAPH OF THE RESULTS OF COMPETITORS NOS. 1, 2 AND 3, SHOWING THE PERCENTAGE MARKS AWARDED FOR EACH SAMPLE

5 and 12 (fig. 4) for example, give almost a straight line. Nevertheless, even where the conditions under which the milk is produced are apparently beyond reproach an occasional high bacterial count may be met with, such as may be caused by a slight

inflammatory condition of the udders of one or two cows. The eighth sample sent in by competitor 9 (fig. 3) suggests such a case. Again, there are cases which, although the bacterial counts are comparatively high, show some degree of consistency, as for example, competitor 10 (fig. 3).

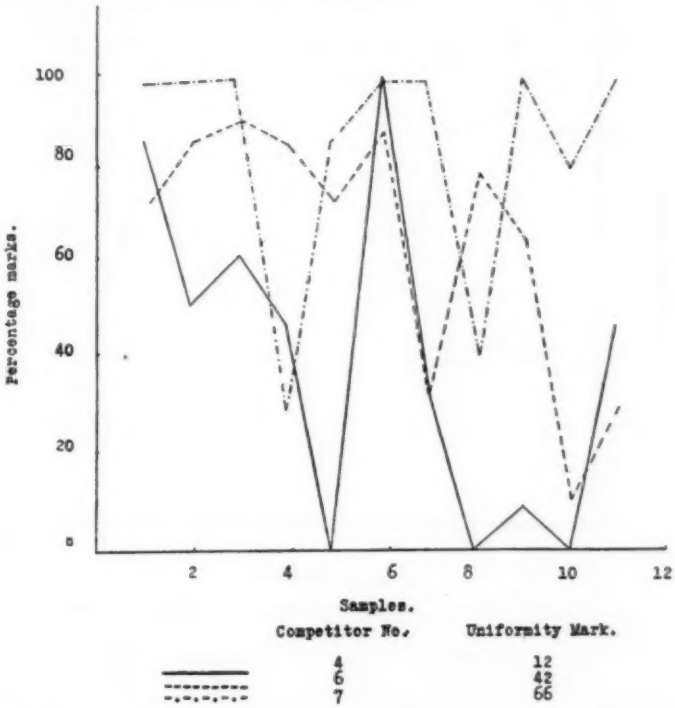

FIG. 2. GRAPHS OF THE RESULTS OF COMPETITORS NOS. 4, 6 AND 7, SHOWING THE PERCENTAGE MARKS AWARDED FOR EACH SAMPLE

It seems very desirable therefore, in view of the great variation which exists in the bacterial counts and keeping quality of successive samples sent in by any one competitor, to devise some method by which the larger number of marks is awarded to those competitors who consistently produce milk of a high bacterial

standard. A method which was adopted in the Yorkshire "Clean Milk Competition" for 1926 for solving this problem is as follows:

Marks are given for bacterial count, keeping quality and B. coli contamination in accordance with the scales suggested in the

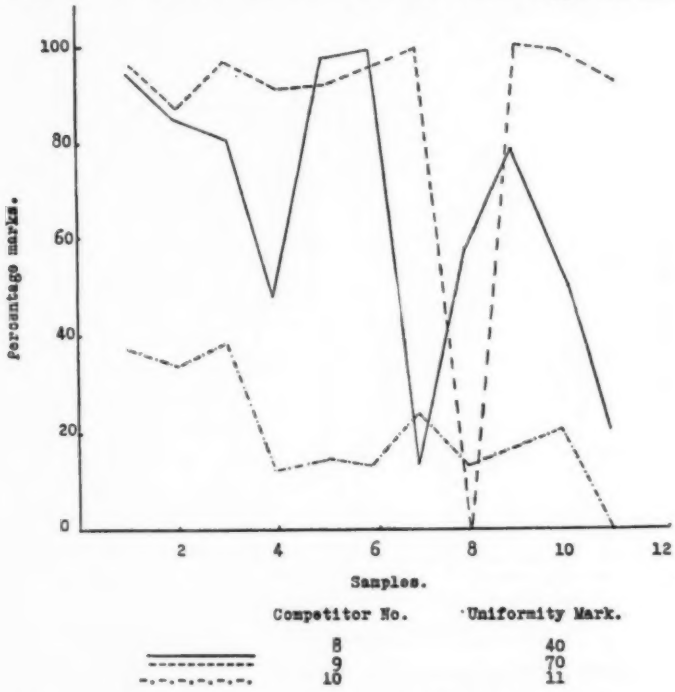

FIG. 3. GRAPHS OF THE RESULTS OF COMPETITORS NOS. 8, 9 AND 10, SHOWING THE PERCENTAGE MARKS AWARDED FOR EACH SAMPLE

"Guide to the Conduct of Clean Milk Competitions." The total marks for each sample is reduced to percentage (see table 1) and the average percentage mark of each competitor's samples determined. The mean variation of the percentage mark of each sample from this average percentage mark is then calculated.

The maximum marks awarded for uniformity is one hundred.

The average percentage mark of each competitor, as calculated above, represents the portion of the uniformity marks which are allocated for lowness of bacterial count and good keeping quality. The mean variation from the average percentage mark of each competitor represents the portion of the *uniformity marks* which

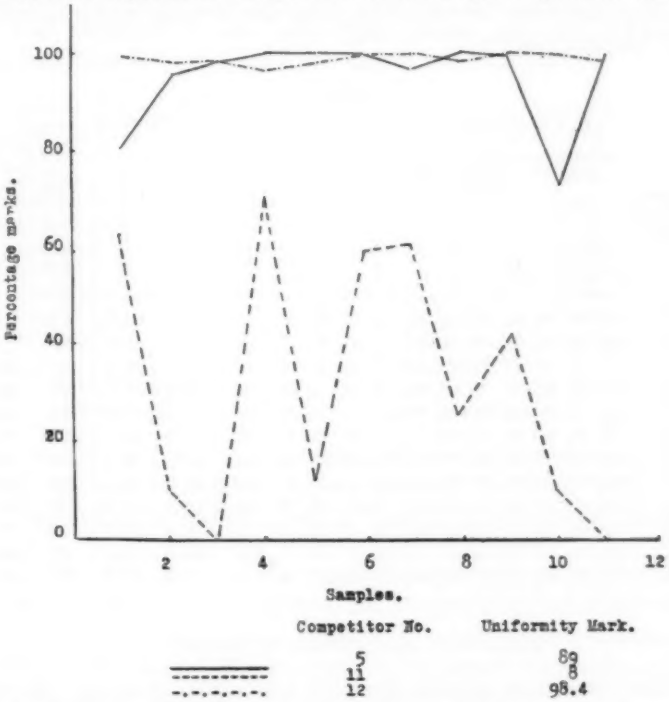

FIG. 4. GRAPHS OF THE RESULTS OF COMPETITORS NOS. 5, 11 AND 12, SHOWING THE PERCENTAGE MARKS AWARDED FOR EACH SAMPLE

are allocated for consistency of bacterial count and keeping quality.[2]

[2] It will be observed that the advantage of taking a hundred as the *uniformity mark* is that the portion of the *uniformity marks* which are allocated for lowness of bacterial count and keeping quality, and the portion of the *uniformity marks* allocated for consistency of bacterial count and keeping quality become numerically the same respectively as the average percentage mark and the mean deviation from the average percentage mark.

If now, the portion of the *uniformity marks* which are allocated for consistency of bacterial count and good keeping quality is deducted from the portion of the *uniformity marks* which are allocated for lowness of bacterial count, a figure is obtained which, while it compensates for low bacterial count and good keeping quality, penalizes for variations from the average bacterial count and keeping quality.

TABLE 1

Marks gained by competitors in a clean milk competition

NUMBER OF COMPETITOR	PERCENTAGE MARKS AWARDED FOR EACH SAMPLE FOR TOTAL BACTERIAL COUNT, B. COLI, AND KEEPING QUALITY											AVERAGE PERCENTAGE MARKS	MEAN VARIATION FROM THE AVERAGE	UNIFORMITY MARK	MARKS FOR EXAMINATION OF MILK (MAXIMUM, 800)	TOTAL MARKS FOR EXAMINATION OF THE MILK AND UNIFORMITY
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11					
1	95	81	94	93	92	91	95	46	69	35	97	81	17.0	64.0	648	712.0
2	61	33	45	98	100	89	70	0	69	90	0	60	29.0	31.0	480	511.0
3	87	87	78	48	65	100	100	70	10	38	0	62	28.0	34.0	496	530.0
4	87	52	62	47	0	100	34	0	10	0	48	40	28.0	12.0	320	332.0
5	81	95	99	100	100	100	96	100	99	72	100	95	6.0	89.0	760	849.0
6	72	86	90	85	73	88	31	79	65	10	30	64	22.0	42.0	512	554.0
7	99	99	100	29	88	99	99	40	100	80	99	85	19.0	66.0	680	746.0
8	95	85	81	47	97	99	13	58	79	47	20	66	26.0	40.0	528	568.0
9	96	87	97	91	92	95	100	0	100	99	93	86	16.0	70.0	688	758.0
10	37	34	38	12	14	13	24	13	17	20	0	20	9.0	11.0	160	171.0
11	62	10	0	71	11	59	61	25	41	10	0	32	24.0	8.0	256	264.0
12	100	99	99	97	99	100	100	99	100	100	99	99	0.6	98.4	792	890.4

EXAMPLE, COMPETITOR 5 (TABLE 1)

The percentage marks awarded for bacterial count, B. coli contamination and keeping quality is as follows:

Sample 1	81
Sample 2	95
Sample 3	99
Sample 4	100
Sample 5	100
Sample 6	100
Sample 7	96
Sample 8	100

Sample 9	99
Sample 10	72
Sample 11	100
Total percentage marks	1042
Average percentage mark	95

The variation of the percentage marks awarded for each sample from the average percentage mark is as follows:

Sample 1	(81–95)	= 14
Sample 2	95–95	= 0
Sample 3	99–95	= 4
Sample 4	100–95	= 5
Sample 5	100–95	= 5
Sample 6	100–95	= 5
Sample 7	96–95	= 1
Sample 8	100–95	= 5
Sample 9	99–95	= 4
Sample 10	72–95	= 23
Sample 11	100–95	= 5
Total variation		71
Average variation		6

The marks for uniformity, i.e., the difference between the average variation and the average percentage mark is $95-6 = 89$.

The *uniformity mark* therefore, which this competitor receives is 89.

It will be seen from the foregoing example and the figures given in table 1 that this method of awarding the *uniformity marks* gives (1) the highest number of marks to those competitors who have maintained a low bacterial count and good keeping quality, as in the case of competitors 5 and 12.

	AVERAGE PERCENTAGE MARKS	MEAN VARIATION FROM THE AVERAGE	UNIFORMITY MARKS
Competitor 5	95	6	89.0
Competitor 12	99	0.6	98.4

(2) A higher *uniformity mark* to those competitors whose average bacterial count and keeping quality, although of a slightly

lower standard, show a greater uniformity than do those competitors who actually have a lower average count and higher keeping quality but lack consistency. For example, the results of competitors No. 6 and 8 compared are as follows:

	AVERAGE PERCENTAGE MARKS	MEAN VARIATION FROM THE AVERAGE	UNIFORMITY MARKS
Competitor 6.....	64	22	42
Competitor 8.....	66	26	40

(3) The least number of marks to those competitors whose count and keeping quality are poor and not even consistently poor, as in the case of competitor 11.

The *uniformity mark* therefore is a figure which compensates for low bacterial count and good keeping quality, yet penalizes for variations from the average bacterial count and keeping quality.

A METHOD OF OBTAINING CRUDE MILK SUGAR AND OTHER SOLIDS FROM SWEET WHEY*

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The annual production of milk sugar (lactose) in the United States is from two to four million pounds, which is only a small part of what could be produced if the demand for it were greater. If the cost of recovering milk sugar from whey could be considerably lessened so that it could compete with other sugars on a more favorable price level, it would be a great help to those who are seeking new outlets for milk sugar. The purpose of this paper is to describe how this may be accomplished.[1]

Whey is the product remaining after the removal of most of the fat and casein from milk either in cheese making or in the manufacture of casein. Its composition varies with the methods employed in removing the fat and casein. A representative analysis is as follows: Water, 93.1 per cent; lactose, 5.0 per cent; proteins, 1.0 per cent; ash (mostly inorganic salts), 0.5 per cent; and fat, 0.4 per cent. The titratable acidity, measured as lactic acid with phenolphthalein as the indicator, varies from 0.10 per cent to about 0.75 per cent, depending on the product that is being made from the milk.

Nearly three-fourths of the mineral salts of milk pass into the whey. The proportion of some of the mineral constituents of milk which pass into the whey in the manufacture of cheddar cheese is given by Berry (1) as follows: Lime, CaO, 36.0 per cent:

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[1] The process described in this paper is covered by the following: Weimar, A. C., Process of extracting soluble albumin from whey, U. S. Patent No. 1,381,605, June 14, 1921; Bell, R. W., Process of separating proteins and other matter from whey in soluble form, U. S. Patent No. 1,600,161, September 14, 1926; and Bell, R. W., Process for the manufacture of crude milk sugar, U. S. Patent No. 1,600,573, September 21, 1926. These patents have been dedicated to the public.

phosphoric acid, P_2O_5, 49.0 per cent; magnesia, MgO, 75.0 per cent; and potash, K_2O, 80.0 per cent.

Several billion pounds of whey are made available annually in this country in the production of cheese and casein. This is from two-thirds to three-fourths of the weight of the milk from which it is obtained. Since the percentage of solids in whey is more than one-half that of milk, it becomes apparent that the proper disposal of these solids is of great economic importance. Most of the whey is now fed to livestock or thrown away. The aim should be to make the solids directly available as human food.

PRESENT METHODS OF MANUFACTURING CRUDE MILK SUGAR[2]

Most of the milk sugar produced in the United States is recovered from grain curd casein whey. In the manufacture of grain curd casein, dilute hydrochloric acid is mixed with skim milk in such proportions as to precipitate the casein and to give the whey a hydrogen ion concentration of 4.1 in terms of pH, or a titratable acidity of about 0.47 per cent. After separation from the casein the whey is condensed, usually in double effect evaporators, to 18° Baumé and run into deep wells for heating to the boiling point, for neutralizing with lime to only a faint alkalinity to litmus paper, and for the settling of the coagulated proteins and insoluble salts. Some people prefer to neutralize the whey to a pH value not greater than 6.2 and to boil it to remove the coagulated proteins and insoluble salts before condensing. Advocates of this method claim that a more favorable medium for the crystallization of the sugar is obtained. When the 18° Baumé whey is neutralized to faint alkalinity to litmus paper, the claim is made that the insoluble material formed by neutralizing and boiling settles better than at a more acid reaction. In both methods the supernatant liquid is siphoned off and run through filter presses. The whey is pressed from the precipitated material at the last stage of the filtering operation.

The filtrate is condensed in a vertical type pan by first filling

[2] For technical information concerning milk sugar see "Lactose: A review" by E. O. Whittier, Chem. Reviews, ii, 85 (1925).

the pan with the sugar syrup and condensing in such a way that the crystals which have formed will serve as nuclei for obtaining and speeding up suitable crystal growth. The last part of the condensing operation, known as the graining process, is carried on slowly to insure the proper formation of sugar crystals. When all the syrup has been drawn into the pan and a concentration sufficient to give a reading of 37.0° to 40.0° Baumé has been attained, the material is removed from the condenser to large crystallizing vats. After slow stirring for one or more hours, accompanied by gradual cooling to approximately 70.0°F., the crystallized sugar is removed from the mother liquor by means of a sugar centrifugal. In one large plant the 37.0° Baumé syrup is left in wooden vats at room temperature for four days to obtain satisfactory crystallization. The filtrate from the centrifugal may be used to obtain more sugar by a second crystallization, it may be dried and used as part of a poultry feed mixture, or it may be discarded.

The crude sugar is washed in the centrifugal and the wash water is added to the next batch of whey. If the crude sugar which contains 85.0 to 90.0 per cent lactose is not produced at a refinery it must be dried on trays in hot air tunnels previous to shipment for refining. The yield of washed and dried crude sugar from one hundred pounds of whey does not exceed three and three-fourths pounds. The filtrate which comes from the press following the removal of coagulated proteins and insoluble salts may be passed by gravity through an activated charcoal filter for the removal of the pigment which gives it a yellow color, again filtered, and evaporated. The sugar recovered from it needs only to be washed, dried, and ground to produce a refined product.

About three-fifths of the proteins of whey are coagulable. The prevailing method of removing them from the whey renders them insoluble. When these proteins, together with certain insoluble salts which make up the sludge from the filter press, are dried they are sold for four or five cents per pound, a price which hardly pays for the cost of drying and handling.

EXPERIMENTAL

This paper describes a process for the recovery of crude milk sugar from fat-free, sweet whey in which the boiling and filter-pressing operations for the removal of coagulable proteins and insoluble salts have been eliminated. It not only has certain advantages of increased yield and greater efficiency of operation over the methods now in use; but it also makes possible the recovery, in a powdered and soluble form, of the solids in the whey other than those removed as crude milk sugar.

Swiss-cheese whey was used in the experimental work because it seemed that the probability of recovering most of the lactose without first removing the coagulable proteins would be increased with a type of whey which was sweet, low in salt content, and very uniform in composition. Swiss-cheese whey was available daily as a result of other experimental work. It had a pH value of 6.4 $\pm$0.05 or a titratable acidity of 0.10 to 0.115 per cent. It was composed of ash, 0.5 per cent; fat, 0.76 per cent; lactose, 5.2 per cent; protein, 0.99 per cent; and water, 92.49 per cent. A lactose content in excess of 5.0 per cent was not expected since more than 5.0 per cent lactose in whey is considered high.

The fat was removed with a suitable separator in order to obtain a more favorable material for the recovery of the sugar. A two-foot vertical type pan and an inclined continuous evaporator were available for condensing. In the latter one thousand pounds of whey could be concentrated to a nine to one ratio in one hour.

EFFECT OF THE REACTION OF THE WHEY

Variations in the concentration and methods of cooling the fat-free whey did not prevent the formation of slime in the sugar centrifugal. Many types of filter cloths of different weaves were used without remedying the difficulty. The slime contained proteins, lactose, and salts in about equal proportions; and when obtained after a thorough whirling of the centrifugal it had a total solids content of 25.0 per cent. The elimination of slime and the consequent ability to obtain a cleaner and quicker separation of the sugar crystals from the mother liquor were made possi-

TABLE 1

Effect of neutralizing sweet whey on the formation of slime

RUN NUMBER	TITRATABLE ACIDITY	TOTAL SOLIDS IN CONDENSED WHEY	YIELD OF CRUDE SUGAR FROM WHEY	YIELD OF LIQUOR FROM WHEY	COMPOSITION OF CRUDE SUGAR				COMPOSITION OF LIQUOR				REMARKS
					Ash	Protein	Water	Lactose	Ash	Protein	Lactose	Total solids	
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	
1	0.11	61.10	5.0	4.8	2.9	4.7	17.0	75.6	7.0	13.3	17.8	38.1	Slime present. Whey not neutralized enough. Tried to force liquor through by extra centrifuging. Poor quality sugar
2	0.08	61.44	4.6	3.2*	.....	.....	.....	.....	4.30	14.70	21.74	40.74	Slime prevented separation of liquor from sugar. Small crystals in condensed whey. Whey not neutralized enough. Sugar very poor
3	0.06	62.10	4.7	5.0	2.05	2.36	11.00	84.50	7.65	14.3	17.05	39.0	Sugar poor in quality and not dry enough. A little slime
4	0.04	62.41	5.0	5.6	1.14	1.75	6.33	91.20	5.04	14.08	21.24	40.36	Sugar excellent. Run satisfactory. No slime

* Some lost.

ble by neutralizing the whey to a pH of 7.3 or a titratable acidity of 0.04 per cent. Neutralizing beyond this point was not necessary, but it was essential that the reaction mentioned be attained in order to be certain that slime would not form. A 5.0 per cent solution of sodium hydroxide was used for neutralizing, care being taken in mixing it with the whey not to cause local concentration of the alkali with consequent precipitation of proteins and salts.

In table 1 typical data are given showing the effect of the reaction of the whey on the formation of slime in the centrifugal and the composition of the unwashed crude sugar and liquor. As the quantity of slime became less the quality of the sugar improved. As soon as the liquor ceased to flow from the centrifugal samples of crude sugar and liquor were taken for analyzing. Other conditions being satisfactory, the success of the process depended upon the proper reaction of the whey before condensing. The figures given in tables 1 and 2, for the per cent of ash in the liquor are, of course, considerably less than the salt content. The ratio of ash to salts is not known. In analyzing for ash, proteins, and lactose in the liquor it was found that the sum of their contents was less than that of the total solids by nearly 4.0 per cent. The results for lactose were low, because of incomplete precipitation of proteins in the analytical procedure. The amount of lactose in the liquor, as it is given in the tables, was found by subtracting the sum of the ash and protein contents from the total solids content. The quantity of salts in the liquor, then, was somewhat greater than that shown by the figures given for ash, and the lactose percentage was somewhat less than indicated.

EFFECT OF CONCENTRATION OF SOLIDS IN THE CONDENSED WHEY

The neutralized whey was warmed in a stream jacketed container to not more than 60°C. (140°F.) before condensing. Cold whey could have been drawn directly into the evaporator with just as satisfactory results. A Baumé reading of 32.0° at 50°C. (131°F.), corresponding to a total solids content of approximately 62.0 per cent, was found to be the best point at which to strike the batch. It was better to exceed the concentration given than not to attain it, because at lower concentrations there was a

definite decrease in the yield of crude sugar. If the total solids content exceeded 64.0 per cent, the resulting product was sometimes not sufficiently fluid to be handled easily at 0°C. or lower. The proper concentration to attain will vary with the type of whey and the temperature used for crystallizing the sugar. Slime formed in many cases if the whey was overcondensed so that it had to be diluted to insure its being sufficiently fluid to pour after crystallization of the sugar.

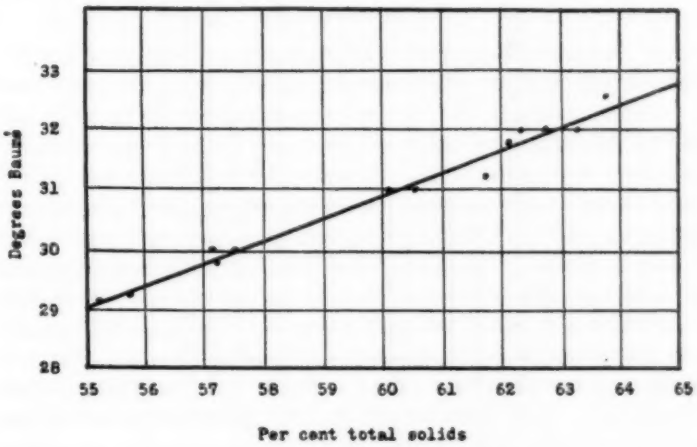

FIG. 1. THE RELATION OF THE BAUMÉ READING TO TOTAL SOLIDS IN CONDENSED FAT-FREE WHEY

Temperatures, 46.0° to 50.0°C., inclusive

It is necessary that a comparatively simple, fairly accurate and quick method be known for determining the proper time at which to strike the batch. An operator will soon learn to judge very closely by the appearance of the material in the pan when the desired concentration has been reached. Figure 1 gives the relation between the Baumé readings taken at temperatures between 46° and 50°C., inclusive, and the total solids content of neutralized and condensed fat-free Swiss-cheese whey.

The results show that the variation in total solids for the same

TABLE 2

Effect of total solids content of condensed whey on the yield of crude milk sugar and liquor from 100 pounds of whey

RUN NUMBER	TITRATABLE ACIDITY OF NEUTRALIZED WHEY	TOTAL SOLIDS IN CONDENSED WHEY	YIELD OF CRUDE SUGAR	YIELD OF LIQUOR	COMPOSITION OF CRUDE SUGAR				COMPOSITION OF LIQUOR				REMARKS
					Ash	Protein	Water	Lactose	Ash	Protein	Lactose	Total solids	
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	
1	0.045	53.22	3.9	8.3	1.52	1.55	8.35	89.00	3.52	10.86	21.12	35.50	Sugar excellent. Yield low. Whey not condensed enough
2	0.04	59.10	4.6	6.0	1.31	1.89	7.67	89.20	4.31	13.56	19.65	37.52	Same as no. 1
3	0.04	61.86	5.3	5.4	1.34	1.49	6.15	91.10	5.10	15.27	19.90	40.27	Sugar excellent. Run satisfactory.
4	0.04	64.81	5.4	5.1	1.97	2.76	9.73	85.54	5.06	15.19	20.29	40.54	Sugar good but inferior to No. 3. Total solids in condensed whey too high

Baumé reading and approximate temperature may be ±0.5 per cent. Changes in methods of concentrating the same type of whey will cause different Baumé readings, even when the temperature and total solids content are the same, principally because of variations in the amount of sugar that has crystallized.

Table 2 shows the effect of the total solids content of the condensed whey on the yield of liquor and unwashed crude sugar.

EFFECT OF TEMPERATURE, SEEDING, AND STIRRING ON CRYSTALLIZATION

Some important factors controlling the crystallization of lactose from whey are concentration, temperature, seeding and stirring. The effect of the concentration on the yield has been given.

Satisfactory crystallization of the sugar was obtained by first cooling the condensed whey to 25°C., by stirring it in cans that were surrounded by cold water and then leaving it for 42 hours in a cooler that had a temperature of 4.0°C. This procedure was employed in the experiments recorded in tables 1 and 2. Satisfactory crystallization of the sugar was also obtained by leaving the condensed whey for eighteen hours in a refrigerator that had a temperature of 0°C. In these experiments the condensed whey was not stirred. Lower temperatures and longer periods for crystallizing did not increase the yield. Cooling the condensed whey with slow stirring to 0°C., or lower, and holding for more than 18 hours has the advantage of giving a larger and drier type of crystal. It increases the likelihood of obtaining good results. Refrigerating at higher temperatures and for shorter lengths of time gave a less desirable material for centrifuging and a decrease in the yield of crude sugar. In the laboratories of the Bureau of Dairy Industry yields of 4 pounds of sugar of 85 per cent purity have been obtained from 100 pounds of Swiss-cheese whey by cooling the condensed whey, without stirring, to 15.0°C., and holding it at that temperature for eighteen hours. In these experiments the whey was condensed to 36.0° Baumé at 46.0°C.

In the crystallization from wheys in which the concentration of solids is high, the lactose will always be in the labile state, nuclei will induce crystallization, and copious seeding should

result in a rapid general formation of crystals. The "graining" process practiced commercially is therefore desirable in obtaining a favorable development of crystals. It is important that crystallization take place as much as possible in the pan. This step has been more successful in the vertical type evaporator which was used than in the continuous unit. In general, the methods now employed in commercial practice for obtaining a satisfactory crystal growth also apply to the recovery of crude milk sugar from neutralized and condensed fat-free sweet whey.

PROPERTIES OF THE LIQUOR AND POWDER

The liquor (filtrate) was not suitable for condensing to obtain a second crop of crystals.

Due to the brownish color of the liquor it was impossible to determine its acidity by a color indicator method. On attainment of equilibrium, that is, as soon as the liquor had been warmed to 24°C. and become free from air, a potentiometric titration showed that its pH value was 0.8 to 1.0 unit less than the pH value of the neutralized whey from which it was obtained.

When held at temperatures low enough to inhibit growth of microörganisms the liquor kept very well. The viscosity increased with time, and if the liquor remained at room temperature for a few days a very definite jellying became apparent.

The liquor was dried by the spray and vacuum drum processes. The appearance and solubility of the powder was governed largely by the method of drying. The powder was light yellow in color, depending on the fineness of the particles and the care taken to prevent unnecessary heating. It emulsified well when dissolved in water and beaten with glucose and cane sugar. The lactalbumin in the powder did not have the property of coagulating with the taking up of water as does egg albumin when it is heated.

Nutrition investigators have done a great deal of work on the food value of casein and lactalbumin. Lactalbumin is a perfect protein in that all of its amino acids are readily utilized in nutrition. The presence in the powder of about two parts of lactalbumin to one part of casein leaves no doubt as to the nutritive

value of the protein constituents, since the casein furnishes cystine which is considered by some to be lacking in lactalbumin. The water soluble vitamin B is found in milk and its products in great abundance. It has been found by long and careful research that this vitamin is not appreciably affected by the usual manufacturing processes used in the handling of milk and its products (2). It is probable, therefore, that the powder is high in vitamin B content. The other ingredients are milk sugar and the soluble salts of milk, thereby making it a desirable ingredient for modified milks. Suggestions which may lead to the manufacture and use of this product will be welcomed.

APPLICATION TO DIFFERENT TYPES OF WHEY

The process as described for Swiss-cheese whey has been applied on an experimental scale to Cheddar-cheese whey and on a semi-commercial scale to Roquefort and Pineapple-cheese whey. The results obtained, although not so satisfactory as those with Swiss-cheese whey, indicate that whey having a titratable acidity of 0.2 per cent of less may be used with good results. Whey having an acidity greater than 0.24 per cent immediately following its separation from the curd does not give satisfactory results either as to the yield or as to the quality of the sugar.

Using rennet casein whey the process was successfully demonstrated on a semi-commercial scale to a representative of one of the large manufacturers of milk sugar. He stated that the unwashed crude sugar obtained during the demonstration was cleaner and freer from inpurities than that made by present commercial methods. The crystals were large and had a gritty feel, due to their sharp corners, thereby indicating that they were of good quality. Other things being equal, fewer impurities will be present in the capillary film in large crystals per unit weight of sugar than in small crystals.

The use of rennet casein whey is to be preferred because the salt content is low and the lactose percentage has not been lessened due to fermentation.

In a later paper it will be shown that whey having a titratable acidity greater than 0.24 per cent immediately following the

removal of the curd gives a precipitate when neutralized with a normal solution of sodium or calcium hydroxide, and that this neutralization precipitate is composed of protein material and tri-calcium phosphate, the proportion depending upon the reaction of the whey immediately following the removal of the curd.

DISCUSSION OF RESULTS AND THEIR APPLICATION

A method has been described for obtaining from whey of 0.2 per cent acid content or less, crude milk sugar and a soluble powder composed of the solids in the fat-free whey other than those removed as crude sugar.

The process now employed in commercial practice for the recovery of milk sugar from whey has been shortened by eliminating expensive boiling and filter-pressing operations. Only one condensing process is needed to obtain a Baumé reading of approximately 32.0°, whereas two operations are necessary in the usual procedure where a concentration of 18.0° Baumé is first attained, followed by a second condensing operation to bring the material from the filter press to test 37.0° to 40.0° Baumé.

Estimating the yield of washed and dried crude sugar to be 4 per cent and of powder 1.5 per cent, 5.5 pounds of finished product per 100 pounds of whey become available for sale. At 10 cents per pound for the crude sugar and at the same price for the powder, the returns per 100 pounds of whey are 55 cents. Two products that will return a profit are obtained instead of one as is now the case in the manufacture of milk sugar.

The market for milk sugar is limited. Improvements in the manufacturing process leading to a substantial reduction in its cost will make the development of new outlets easier. It is hoped that the results of this paper will be an aid toward that end and therefore bring about a better and more extensive utilization of the solids in whey.

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